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Building construction — Measuring instruments — Procedures for determining accuracy in use —

Part 1: Theory

Construction immobilière — Instruments de mesure — Procédures de détermination de l'exactitude d'utilisation —

Partie 1: Théorie

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council. They are approved in accordance with ISO procedures requiring at least 75 % approval by the member bodies voting.

International Standard ISO 8322-1 was prepared by Technical Committee ISO/TC 59, *Building construction.*

Users should note that all International Standards undergo revision from time to time and that any reference made herein to any other International Standard implies its latest edition, unless otherwise stated.

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Building construction — Measuring instruments — Procedures for determining accuracy in use —

Part 1: Theory

0 Introduction

This International Standard consists of a series of parts specifying test procedures to be adopted when determining and assessing the accuracy in use of measuring instruments in building construction. The first part gives the theory; subsequent parts give the procedures for determining the accuracy in use of measuring instruments for measurements. The complete series will consist of the following parts:

- Part 1: Theory.
- Part 2: Measuring tapes.
- Part 3: Optical levelling instruments.
- Part 4: Theodolites.
- Part 5: Optical plumbing instruments.
- Part 6: Laser instruments.
- Part 7: Instruments when used for setting out.
- Part 8: Electronic distance-measuring instruments.

Other International Standards for testing measuring instruments for land surveying purposes, and for measuring procedures in ordnance survey, are in preparation.

1 Scope

This part of ISO 8322 gives the formulae used in the specification of test procedures to be adopted for the determination and assessment of the accuracy in use of measuring instruments.

2 Field of application

The theory given in this part of ISO 8322 applies to the procedures used in building construction when determining and assessing the accuracy of surveying, check and compliance measurements, setting out, checking processes or when obtaining accuracy data. These procedures assume the use of measuring methods in which the systematic errors can be largely compensated for or disregarded.

3 References

ISO 3534, *Statistics — Vocabulary and symbols.*

ISO 4463-1, *Measurement methods for building — Setting-out and measurement — Part 1: Planning and organization, measuring procedures, acceptance criteria.*

ISO 7077, *Measuring methods for building — General principles and procedures for the verification of dimensional compliance.*

ISO 7078, *Building construction — Procedures for setting out, measurement and surveying — Vocabulary and guidance notes.*

4 General

4.1 Before commencing surveying, check and compliance measurements, when obtaining accuracy data or setting out, it is important that the operator investigates that the accuracy in use of the measuring equipment is appropriate to the intended measuring task. This International Standard recommends that the operator carries out test measurements under field conditions to establish the accuracy achieved when he uses a particular instrument and its ancillary equipment.

To ensure that the assessment takes account of various environmental influences, two series of measurements need to be carried out under different conditions. The particular conditions to be taken into account may vary depending on where the tasks are to be undertaken. These conditions will include variations in air temperature, wind speed, cloud cover and visibility. Note should also be made of the actual weather conditions at the time of measurement and the type of surface over which the measurements are made. The sets of conditions chosen for the tests should match those expected when the intended measuring task is actually carried out. See ISO 7077 and ISO 7078.

Successive parts of this International Standard give detailed procedures for determining the accuracy in use for specific types of instruments. For those instruments not covered in a separate part, the theory given in this part can be used as a basis for devising suitable test procedures. In such cases the minimum values taken for m and n should be 4 and 30 respectively (see 5.1 and 5.2). Such test procedures should be carried out over the range of measurements for which the instrument is to be used.

For each of the tests to be adopted for different tasks and described in detail in parts 2 to 8 of this International Standard, the preferred minimum sample size is indicated in the relevant clauses. However, if particular circumstances dictate the acceptance of smaller sample sizes, this must be in the knowledge that the assessment will be less reliable.

All procedures are designed so that the systematic errors are largely eliminated and assume that the particular instruments are in known and acceptable states of user adjustment according to methods detailed in the manufacturer's handbooks.

Accuracy in use procedures require repeat tests to be made with the same instrumentation and the same observer, within a short interval of time. These are "repeatability conditions" as defined in ISO 3534.

The accuracy in use is expressed in terms of the standard deviation.

4.2 The figure indicates schematically the decisions to be made when establishing that the accuracy associated with a given surveying method and particular measuring equipment is appropriate to the intended measuring task. In particular, the decisions apply when adopted by a particular operator under a range of environmental conditions which are likely to occur when the task is actually carried out. Where the contract documentation specifies the required tolerance for the intended measuring task, it is recommended that this tolerance, which is normally given in terms of the permitted deviation $\pm P(P = 2{,}5\,\sigma)$ of the measuring task, is compared with the accuracy in use data obtained either from previous accuracy in use tests or from general data A which indicate the expected accuracy in use of given measuring equipment. On those occasions that the previously obtained data indicates that the accuracy in use associated with the given measuring equipment exceeds the specified permitted deviation of the measuring task, consideration should be given to either selecting a different method and/or a more precise instrument, or discussing with the designer the need for such a small permitted deviation. See ISO 4463-1.

Before obtaining an overall estimate of the accuracy in use, it is recommended that each standard deviation for a given series of measurements undertaken under particular environmental conditions is compared, as indicated in the figure, with the specified permitted deviation. Where the comparison shows that the specified permitted deviation has not been achieved for one series of measurements, an additional series of measurements should be carried out under as near as possible similar environmental conditions to those which applied in that original series of measurements.

Assumptions: $\pm P$ is the permitted deviation of the measuring task

A is the accuracy in use, generally expressed as deviation $\pm A$; (both $\pm P$ and $\pm A$ are considered to include the dimensional variability associated with $\pm$ 2,5 times the standard deviation σ)

s are the deviations obtained in the field tests

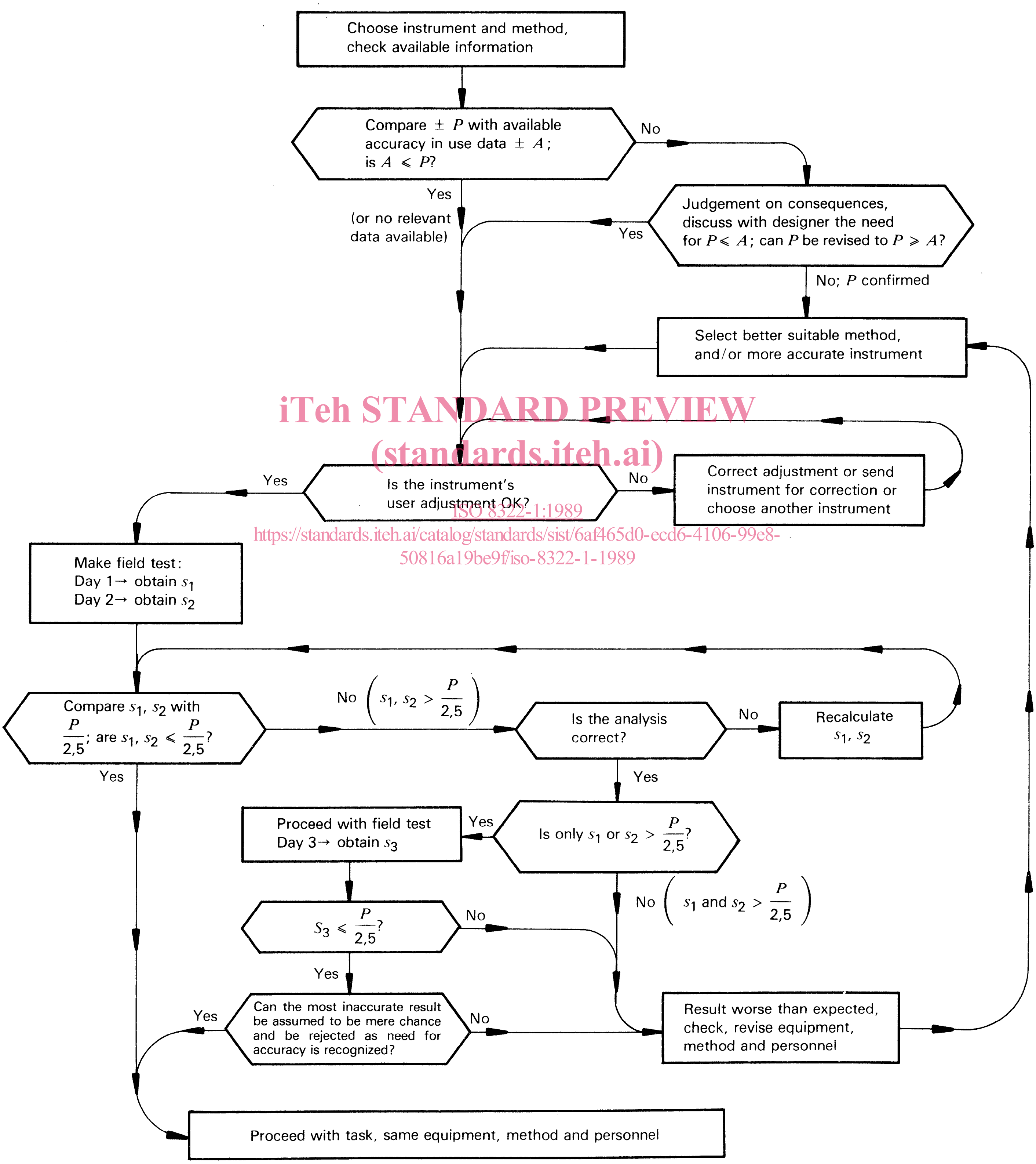

Figure 1 — Flow diagram for accuracy in use tests

5 Formulae

The following formulae are required for use at the evaluation stage of most of the procedures given in the subsequent parts of this International Standard. They indicate how the achieved accuracy in use, expressed in terms of standard deviation or mean square error, is estimated by first calculating the individual standard deviations or mean square errors for each of the series of measurements and then by combining statistically each of these individual standard deviations or mean square errors. The formulae are given in general terms such that the number of series of measurements and the number of individual measurements within each series is not defined explicitly.

5.1 Calculation of the standard deviation for a single series of measurements using mean values

5.1.1 Let n_j be the number of measurements in the jth series.

5.1.2 Let x_{ij} be the value of the ith measurement of the jth series.

5.1.3 The arithmetic mean, $\overline{x}$, of the values measured in the jth series of measurement is

$$\overline{x_j} = \frac{1}{n_j} \sum_{i=1}^{n_j} x_{ij}$$

5.1.4 Let v_{ij} be the deviation of the value of the ith measurement from the arithmetic mean within the jth series of measurements. Thus

$$v_{ij} = x_{ij} - \overline{x_j}$$

To minimize the effect of rounding errors, the calculation of each division v should be carried out to the nearest 0,1 value of the last observed digit. As an arithmetic check the sum of the deviations should be zero.

5.1.5 Let $\sum_{i=1}^{n_j} v_{ij}^2$ be the sum of squares of all the deviations (v_{ij}) within the jth series of measurements. Thus

$$\sum_{i=1}^{n_j} v_{ij}^2 = v_{1j}^2 + v_{2j}^2 + \ldots + v_{nj}^2$$

5.1.6 Let f_j be the number of degrees of freedom for the jth series of measurements, where

$$f_j = n_j - 1$$

5.1.7 Let s_j be the standard deviation for the jth series of measurements, where s_j is calculated thus

$$s_j = \sqrt{\frac{\sum_{i=1}^{n_j} v_{ij}^2}{f_j}}$$

5.2 Calculation of the overall standard deviation for several series of measurements using mean values

The standard deviation obtained for each of the jth series of measurements is considered to be a separate estimate of the overall standard deviation of the measurement. It is assumed that each of these estimates is equally valid. The following formulae indicate how the individual standard deviations are combined to give one overall standard deviation which takes equal account of the standard deviations calculated for each series of measurements.

5.2.1 Let m be the number of series of measurements.

5.2.2 As the true value of each of the m measurements series cannot be determined, the arithmetic mean of each series is accepted as the best estimate of the true value.

5.2.3 Let s be the overall estimate of the standard deviation, where s is calculated thus

$$s = \left[\frac{1}{m} (s_1^2 + s_2^2 + \ldots + s_m^2) \right]^{1/2}$$

5.3 Calculation of the standard deviation for a single series of measurements using double observations

5.3.1 Let n_j be the number of a double observation set in the jth series.

5.3.2 Let x_{ij1} and x_{ij2} be the values of the ith set of the double observations in the jth series.

5.3.3 Let d_{ij} be the difference of the two values of the double measurements of the ith set of the jth series

$$d_{ij} = x_{ij1} - x_{ij2}$$

5.3.4 Let $\sum_{i=1}^{n_j} d_{ij}^2$ be the sum of square of all differences d_{ij} within the jth series of measurements. Thus

$$\sum_{i=1}^{n_j} d_{ij}^2 = d_{1j}^2 + d_{2j}^2 + \ldots + d_{nj}^2$$

5.3.5 Let s_j be the standard deviation for the jth series of measurements, where s_j is calculated thus

$$s_j = \sqrt{\frac{\sum_{i=1}^{n_j} d_{ij}^2}{2n_j}}$$

5.4 Calculation of the overall standard deviation for several series of measurements using double observations

The following formulae indicate how the individual standard deviations are combined to give one overall standard deviation which takes equal account of the standard deviations calculated for each series of measurements.

5.4.1 Let m be the number of series of measurements.

5.4.2 Let s be the overall estimate of the standard deviation where s is calculated thus

$$s = \left[\frac{1}{m} (s_1^2 + s_2^2 + \ldots + s_m^2) \right]^{1/2}$$

5.5 Calculation of the standard deviation for a single series of measurements using values accepted as true

5.5.1 Let n_j be the number of measurements in the jth series.

5.5.2 Let x_{ij} be the value of the ith measurement of the jth series.

5.5.3 Let $\overline{x}_{ij}$ be the true value or the value accepted as true of the ith measurement of the jth series, derived from another measurement procedure with a higher accuracy.

5.5.4 Let ε_{ij} be the deviation of the observed value of the ith measurement from the true value or the value accepted as true. Thus

$$\varepsilon_{ij} = x_{ij} - \overline{x}_{ij}$$

5.5.5 Let $\sum_{i=1}^{n_j} \varepsilon_{ij}^2$ be the sum of the squares of all the true deviations (ε_{ij}) (or the values accepted as true) within the jth series of measurements. Thus

$$\sum_{i=1}^{n_j} \varepsilon_{ij}^2 = \varepsilon_{1j}^2 + \varepsilon_{2j}^2 + \ldots + \varepsilon_{nj}^2$$

5.5.6 Let m_j be the mean square error for the jth series of measurements where m_j is calculated thus

$$m_j = \sqrt{\frac{\sum_{i=1}^{n_j} \varepsilon_{ij}^2}{n_j}}$$

5.6 Calculation of the overall mean square error for several series of measurements using true values

5.6.1 Let k be the number of series of measurements.

5.6.2 Let M be the overall mean square error, where M is calculated thus

$$M = \left[\frac{1}{k} (m_1^2 + m_2^2 + \ldots + m_k^2) \right]^{1/2}$$

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